A HRS Thermal Analysis with an additional 30% MARS Heat Load and Radiation effect from the Target Rod

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Updated HRS Thermal analysis

- Based on the “A preliminary of thermal analysis for HRS” (see Mu2e_doc_3503-v1), two recommendations:

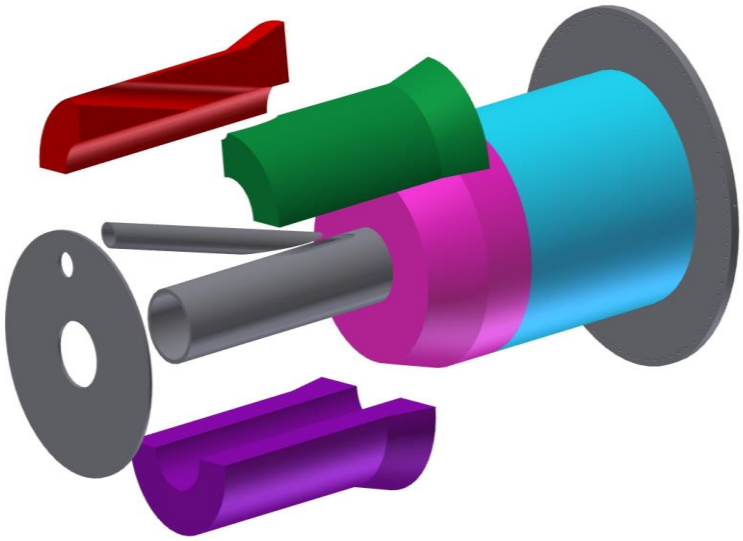
  a) Adding an additional 30% heat load for HRS to cover the uncertainty from MARS simulation.

  b) Including the radiation effect from the target.

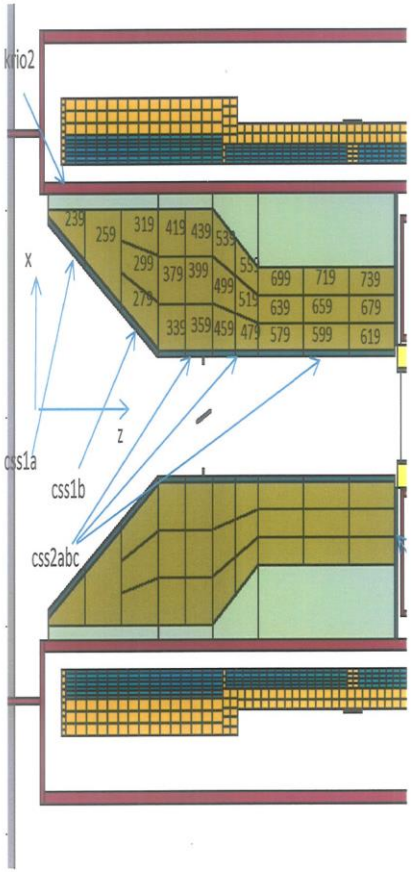
- 1st item is relatively simple _ by multiplying a scaling factor of 1.3 to the original MARS heating map, provided by Vitaly.

- 2nd item will need some more works.

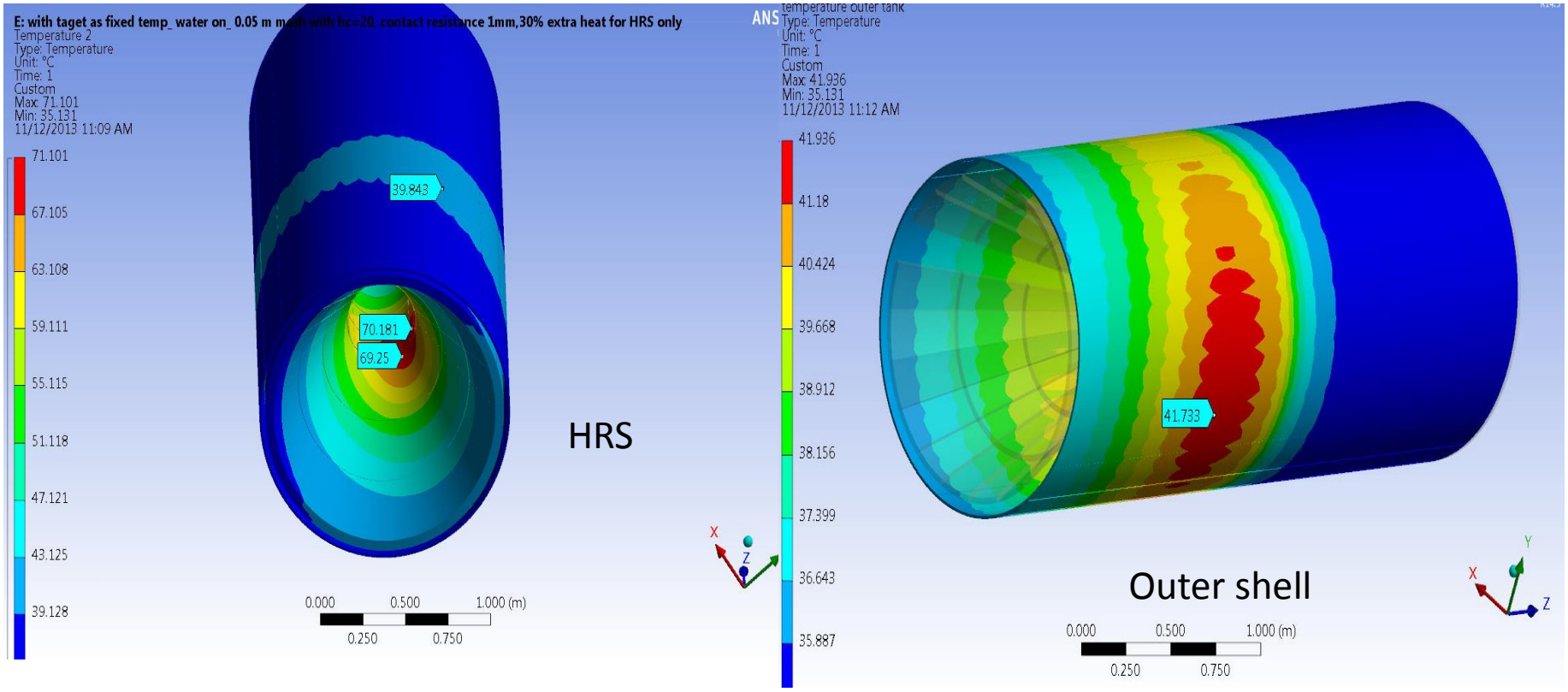
30% additional heat load for HRS with the same geometry



NREG	VOLNAME	Material	RHO	VOL	Q
			g/cm3	cm3	W/cm3
5	krio2	S316	7.92E+00	8.55E+05	6.15E-01
33	cwtr1	Water	1.00E+00	2.73E+05	9.67E+00
34	cwtr2	Water	1.00E+00	1.34E+05	6.38E+00
35	cwtr3	Water	1.00E+00	3.13E+05	5.67E+00
36	cwtr4	Water	1.00E+00	1.47E+06	3.55E+00
39	css1a	S316	7.92E+00	1.99E+03	2.58E-01
40	css1a	S316	7.92E+00	2.00E+03	2.55E-01
41	css1a	S316	7.92E+00	1.98E+03	2.55E-01
42	css1a	S316	7.92E+00	1.99E+03	2.69E-01
43	css1a	S316	7.92E+00	2.00E+03	2.99E-01
44	css1a	S316	7.92E+00	1.98E+03	3.45E-01
45	css1a	S316	7.92E+00	1.98E+03	4.71E-01
46	css1a	S316	7.92E+00	1.94E+03	7.92E-01
47	css1a	S316	7.92E+00	2.00E+03	9.19E-01
48	css1a	S316	7.92E+00	2.02E+03	1.10E+00
49	css1a	S316	7.92E+00	2.00E+03	1.02E+00
50	css1a	S316	7.92E+00	2.02E+03	9.12E-01
51	css1a	S316	7.92E+00	2.02E+03	5.67E-01
52	css1a	S316	7.92E+00	1.99E+03	4.30E-01
53	css1a	S316	7.92E+00	2.02E+03	3.52E-01
54	css1a	S316	7.92E+00	2.01E+03	3.06E-01
55	css1a	S316	7.92E+00	1.97E+03	2.77E-01
56	css1a	S316	7.92E+00	1.98E+03	2.62E-01



Temperature solution of HRS with 30% additional MARS heat load



The Inner liner_ T=71 C; The Outer shell _ T=~42 C; Compared with the earlier result:

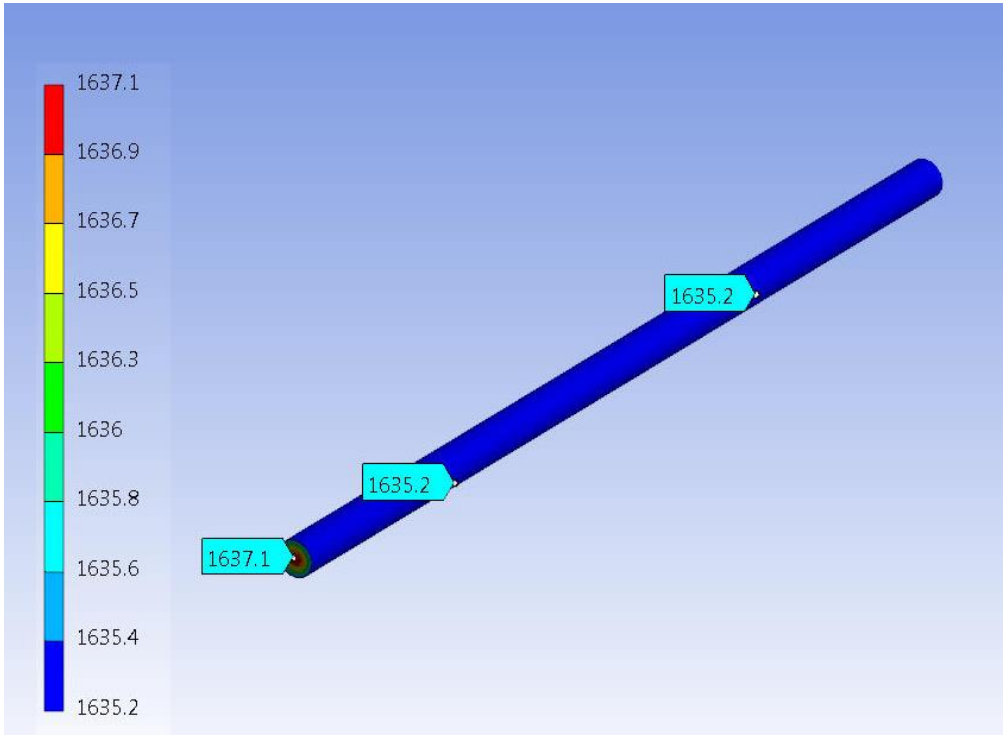
a) The inner liner temperature changes from 63 C to71 C.
b) The outer shell temperature changes from 40.24 C to 42 C largely due to the water cooling effect.
c) Outer shell temperature NOT very sensitive to 30% heat increase from MARS.

Radiation effect from the target Rod

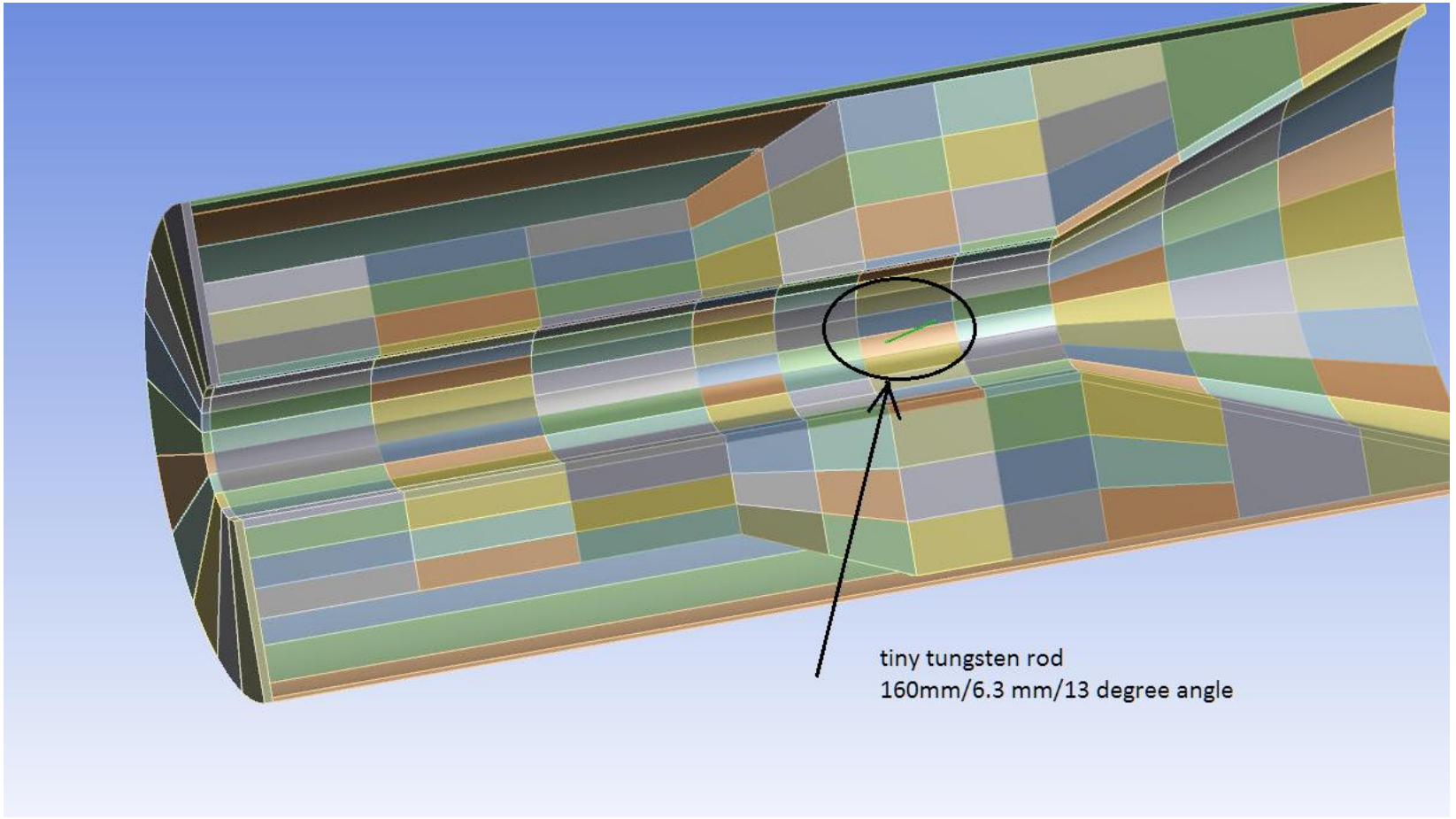
- From CDR, the energy deposits into the target Rod is 700 W.
- The tungsten target rod temperature is around ~1700 C from Rutherford study by C. J. Densham and others.
- We'll do two things here
- a) Duplicated the Rutherford result by using 700w and emissivity =0.3 as indicated.
- b) Create a tiny tungsten Rod in the HRS thermal model and turn on the radiation.

Radiation model with a single Rod with 700 w and emissivity=0.3

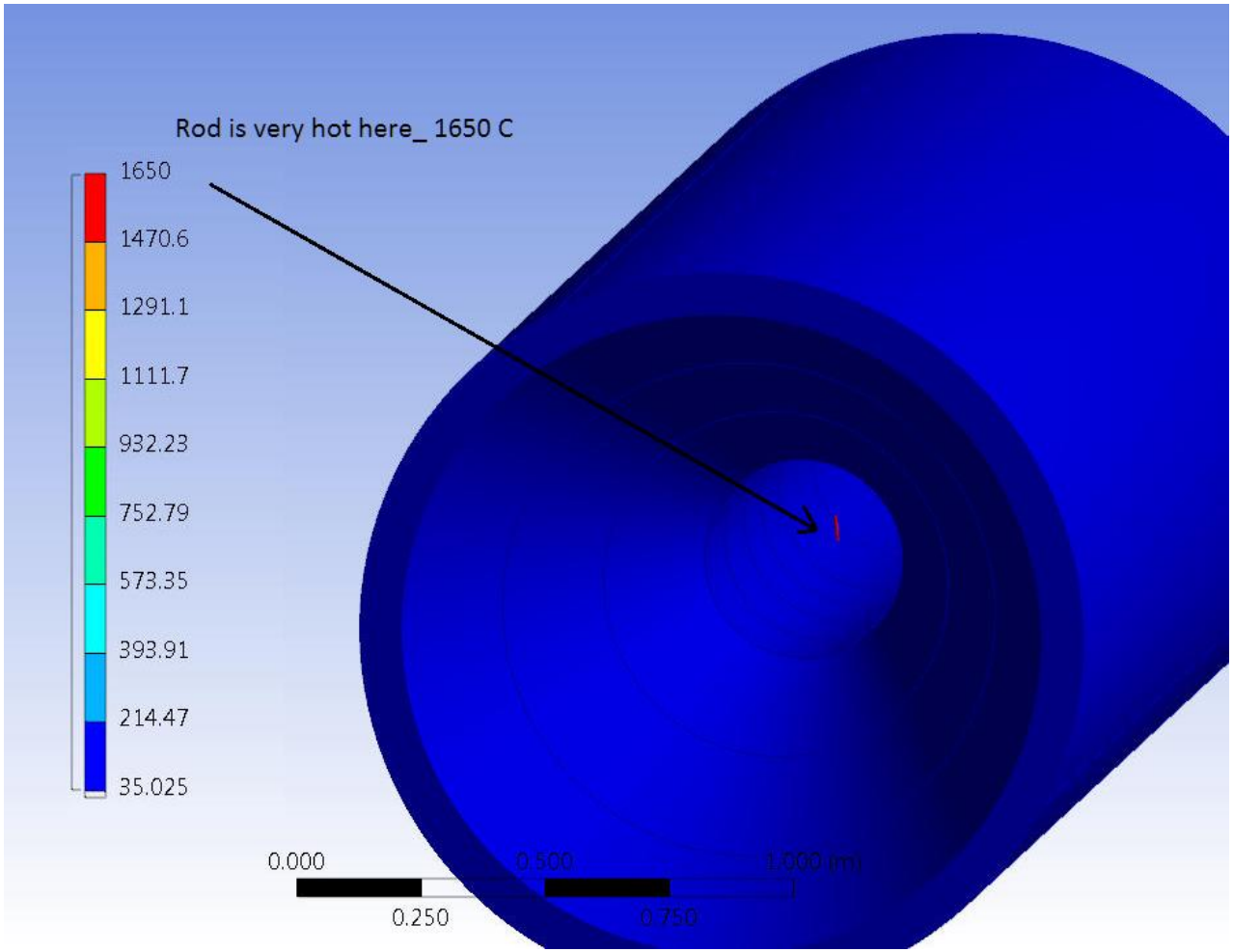
- With a simple uniform 700 w heat, the temperature of tungsten rod is ~1650 C, very similar to Rutherford result, which used an actual MARS heat map for a more comprehensive study.
- Result indicates that the rod temperature is not effected much by the ambient temperature, which also noted in Rutherford study due to $Q = A\sigma\varepsilon(Th\text{^}4 - Tc\text{^}4)$, 2nd term is too small to count for.
- Therefore, we'll use the Trod=1650 C as a fixed temperature for the radiation effect study for HRS



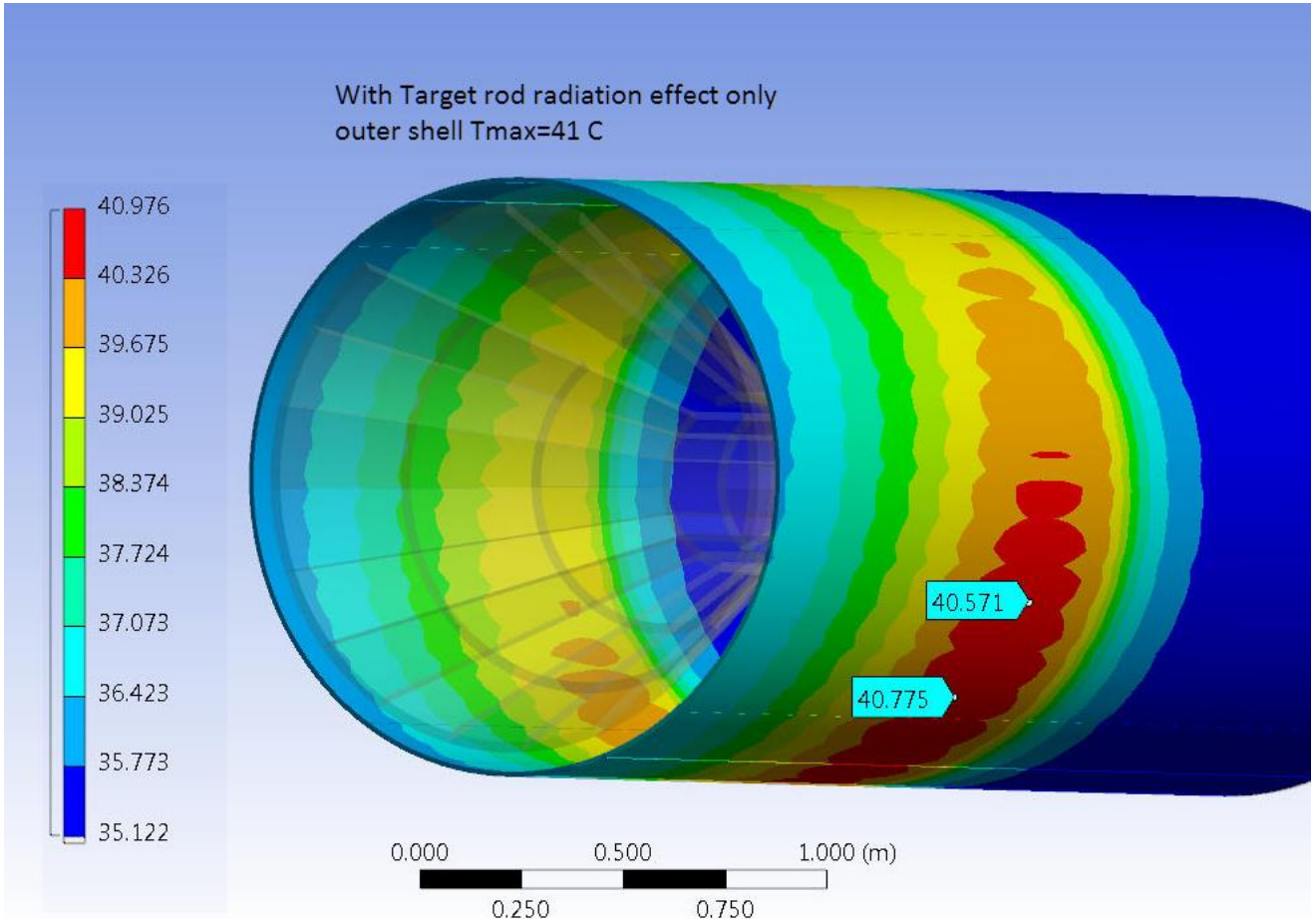
HRS with the target Rod



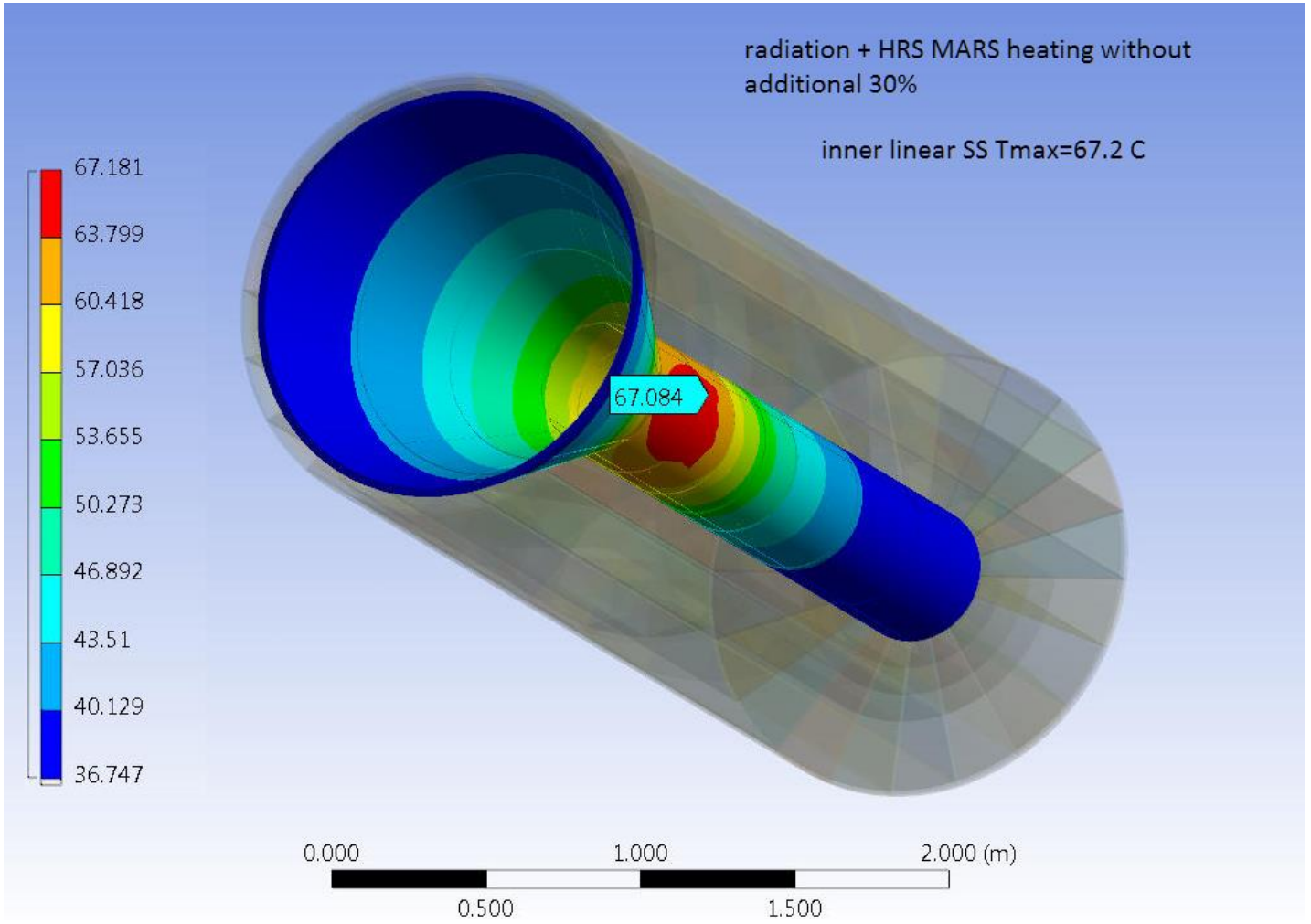
Temperature profile for HRS with a target rod



Radiation + HRS MARS heating without additional 30% heat load outer shell temperature (C)_ Tmax (outer shell)=~41 C



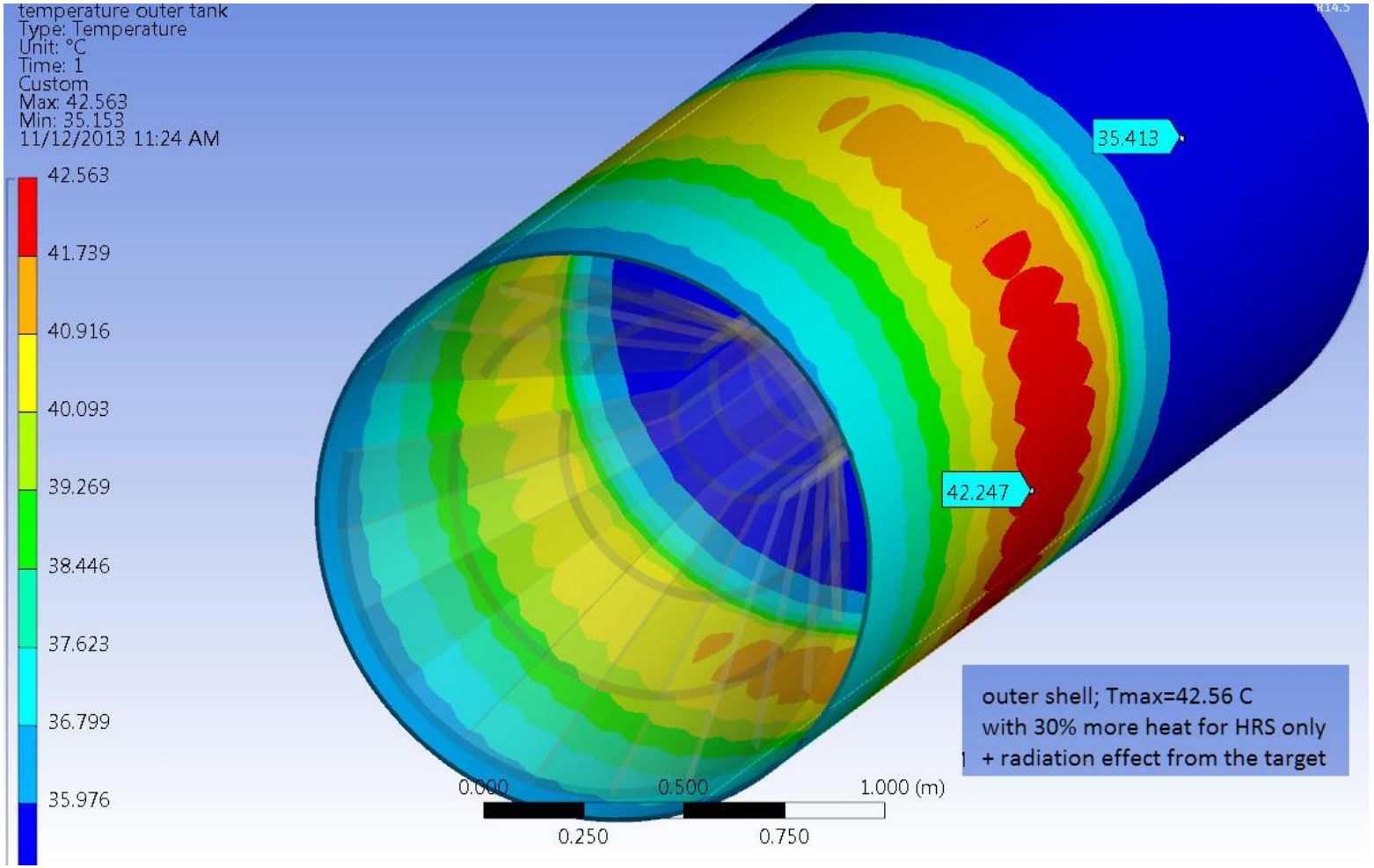
Radiation + HRS MARS heating without additional 30% heat load _inner liner temperature (C)_ Tmax (inner liner)=~67.2 C



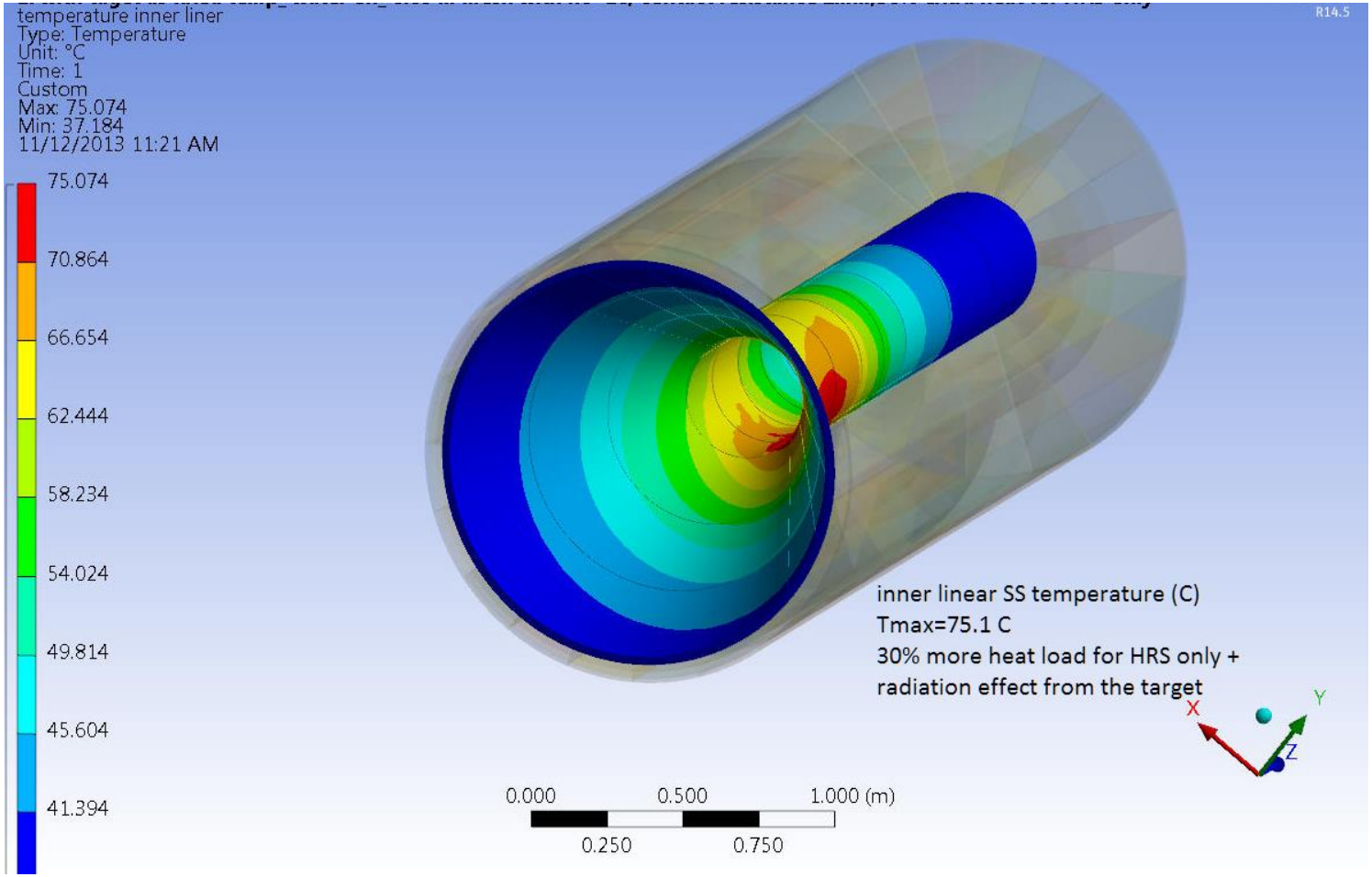
Radiation + HRS MARS heating with an additional 30% heat load

Outer shell temperature Tmax (outer shell)= 42.24 C

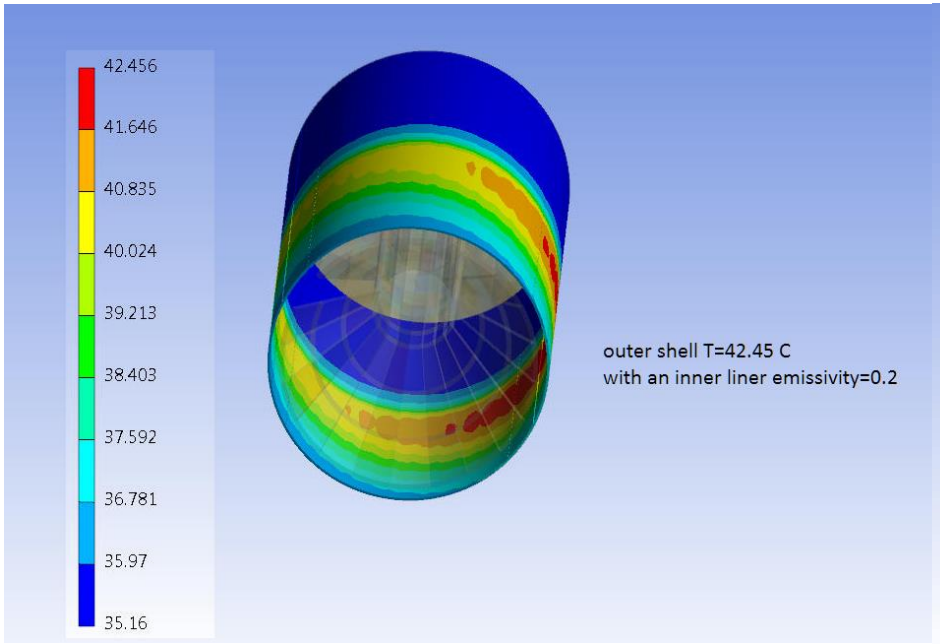
(Compared with 40.24 C w/o both 30% more heat and radiation effect)

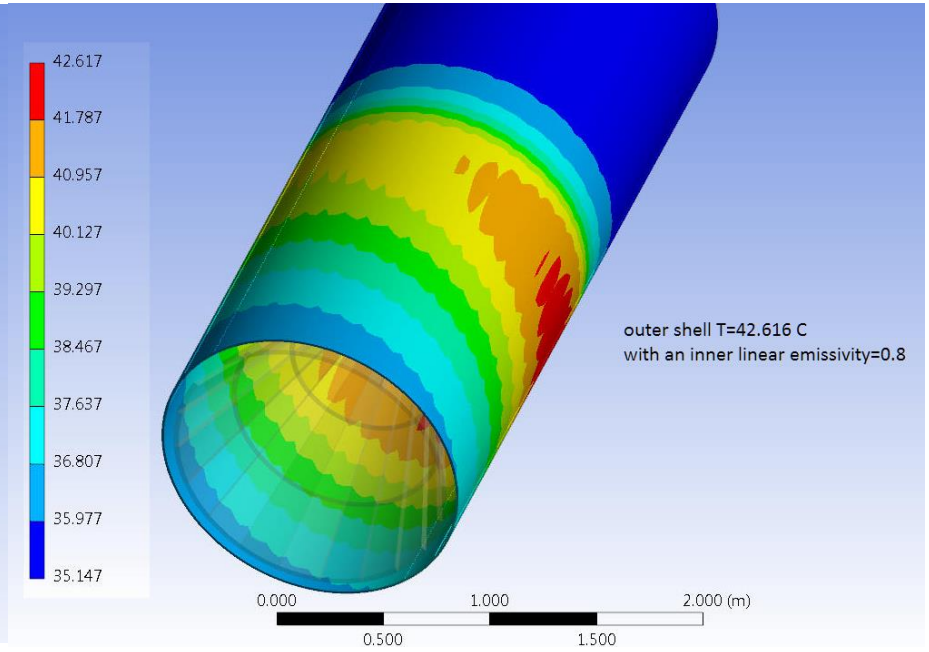


Radiation + HRS MARS heating with additional 30% heat load
Inner liner temperature T=75.1 (C)
(Compared with 63 C w/o both additional 30% heat and radiation effect)



Effect of emissivity of the inner liner





There is no emissivity given for the inner liner. The literature survey indicates that it could vary from 0.2 ~0.8 depending upon the surface finishing. The calculation uses 0.4. The parametric study indicates the outer shell temperature does not change much as the emissivity of inner liner varies.

Summery of Result

	100% HRS MARS heat map _ earlier study	130% HRS MARS heat map	Radiation effect from the target +100% HRS MARS heat map	Radiation effect from the target +130% HRS MARS heat map
Outer shell temperature (C)	40.24	42	41	42.5
Inner shell temperature (C)	63	71	67.1	75.1

Worst case

It seems that the current design with the water cooling will keep the **<u>outer shell temperature < 45 C</u>**, even including 30% additional MARS heating for HRS and radiation effect.

Reference

1) C.J Densham & etc, “Conceptual Design Study of Mu2e Experiment Pion Production Target Components and Systems”, STFC Rutherford Appleton Laboratory, Aug 24, 2012
2) Ang Lee, “A Preliminary Thermal result for HRS”, Mu2e-doc-3503-v1, Oct 17,2013